1974

A planning study on the electrical load requirement for the new town of Pattonsburg

Javad Yousefian

A PLANNING STUDY ON THE ELECTRICAL LOAD REQUIREMENT FOR THE NEW TOWN OF PATTONSBURG

by

JAVAD YOUSEFIAN, 1944

A THESIS

Presented to the Faculty of the Graduate School of the

University of Missouri - Rolla

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

in

ENVIRONMENTAL AND PLANNING ENGINEERING

1974

Approved by

Lawrence W. Sieck (Advisor

V. A. C. Gevecker

Xavier JR Avula

ABSTRACT

Because of an Army Corps of Engineer proposed new dam on the Grand River, the original town of Pattonsburg, Missouri was to be inundated by the resulting lake reservoir formed above the dam. The city planners proposed the relocation of the town site adjacent to the new lake, forming a lake side community attractive to both a residential population and for industrial locations.

The electrical power loads of New Pattonsburg's residential, industrial, commercial, and municipal areas, as well as its street lighting power requirements, were planned for a population of 50,000. Statistical analysis of demographic surveys was employed to help predict the location and size of electrical loads per human needs and human density.

Estimate of the hydroelectric power output from the new dam built on the Grand River was made on a basis of 12 recorded, consecutive annual average discharge rates of the river.

The present transmission lines which surround the site of New Pattonsburg are assumed to have sufficient capacity to supply the new town's electrical power requirements.

The main electrical transmission line and power layout distribution of New Pattonsburg is planned to be accomplished by an underground distribution network. The cost of this distribution layout and the main transmission line is roughly estimated to be 8-12 million dollars.

ACKNOWLEDGEMENTS

The professional advice and leadership of my advisor, Dr. Lawrence K. Sieck, is gratefully acknowledged and sincerely appreciated. The valuable advice and constructive criticism of Dr. X. J. Avula, Dr. J. D. Morgan, and Professor V. A. Gevecker is sincerely appreciated. Thanks also go to those who helped me with gathering data, and Mrs. Mary McKinney for typing this manuscript.

I express my deep feelings of love and respect toward my parents whose help and inspiration made my education possible.

TABLE OF CONTENTS

Table of Contents (Continued) Page

LIST OF FIGURES

LIST OF TABLES

List of Tables (Continued) Page

LIST OF MAPS

I. INTRODUCTION

Pattonsburg is a small rural, northwestern town located in the Green Hills region of Daviess County, Missouri. The need for the relocation of this town and subsequent establishment of a new Pattonsburg resulted from the threatened inundation of the present town site by the proposed Corps of Engineers reservoir that is scheduled for completion in the late 1970's.

A. BACKGROUND

The original town of Pattonsburg was established over one hundred years ago and grew steadily during its first years. But since the plan for the federal reservoir was proposed in 1930[1], (p. 10) the population of Pattonsburg has decreased from 1,200 inhabitants to a mere 540 in 1970. In 1965, Congress gave final approval for the reservoir project, and the future of Pattonsburg was sealed. A survey conducted at that time shows that 75 percent of the Pattonsburg citizens chose to relocate their town. The Missouri Department of Community Affairs became involved in the Pattonsburg project at the request of the City of Pattonsburg and the Green Hills Regional Planning Commission. The Missouri Department of Community Affairs was responsible for preparing the application for establishing a new town of Pattonsburg and was assisted by the support and encouragement of Senator Stuart Symington, Senator Thomas F. Eagleton, and Representative W. R. Hull, Jr., the congressional delegation representing the state and that region. Governor Warren E. Hearnes also added his endorsement and support for the proposal for the new town of Pattonsburg. Senator Symington addressed the United States Senate and asked for support of a new Pattonsburg as a prototype of "new towns of the future." He proposed the Pattonsburg project as a case study of a rural, new town capable of stabilizing and eventually reversing the rural-to-urban migration trend so typical of rural areas in Missouri and the Midwest. Senator Symington's contention was that in order for new community development to become truly relevant in states such as Missouri, it must serve two functions: 1) assist to stimulate growth in declining rural areas, and 2) "act as an integral part of balanced, regional development policy."[1] (p. 10). Planners at the Missouri Department of Community Affairs followed Senator Symington's guidelines in arranging their proposal, and the Department of Housing and Urban Development approved the application and announced the Comprehensive Planning Grant in September, 1970.

Since September, 1970, two outside factors have affected the study undertaken by the planners. These factors are the constraints and critical assumptions. The constraints imposed upon the study had involved limited time and funds. The effective study period took about eight months. Two months were spent in program organization, a search for non-federal funds, contacting and interviewing of consultants, and gathering basic data and information, and six months were spent in the implementation of the actual analysis and study.

B. ASSUMPTIONS

The second factor influencing the planners' study was certain critical, logical assumptions made to facilitate their project.

1. The construction of the Pattonsburg reservoir, as proposed by the Corps of Engineers, will begin in 1978 and be completed before 1983.
2. The completion of the proposed Interstate Highway 35, including a bridge over the reservoir, will be accomplished by 1976. This will provide Pattonsburg with vehicular access to Kansas City from the south, and Des Moines, Iowa, to the north.
3. Relocation of the existing town of Pattonsburg will be effected by 1975. Encouragement at the local, state, and federal levels will help insure the establishment of an attractively planned and economically suitable and viable new town of Pattonsburg.
4. And because of the interest generated during the study period, it is logical to assume that a high level of support and continued interest will continue from local governmental units, the Green Hills Regional Planning Commission, the Missouri Department of Community Affairs, the Governor's

Office, Senator Symington, Senator Eagleton, and Congressman Hull.

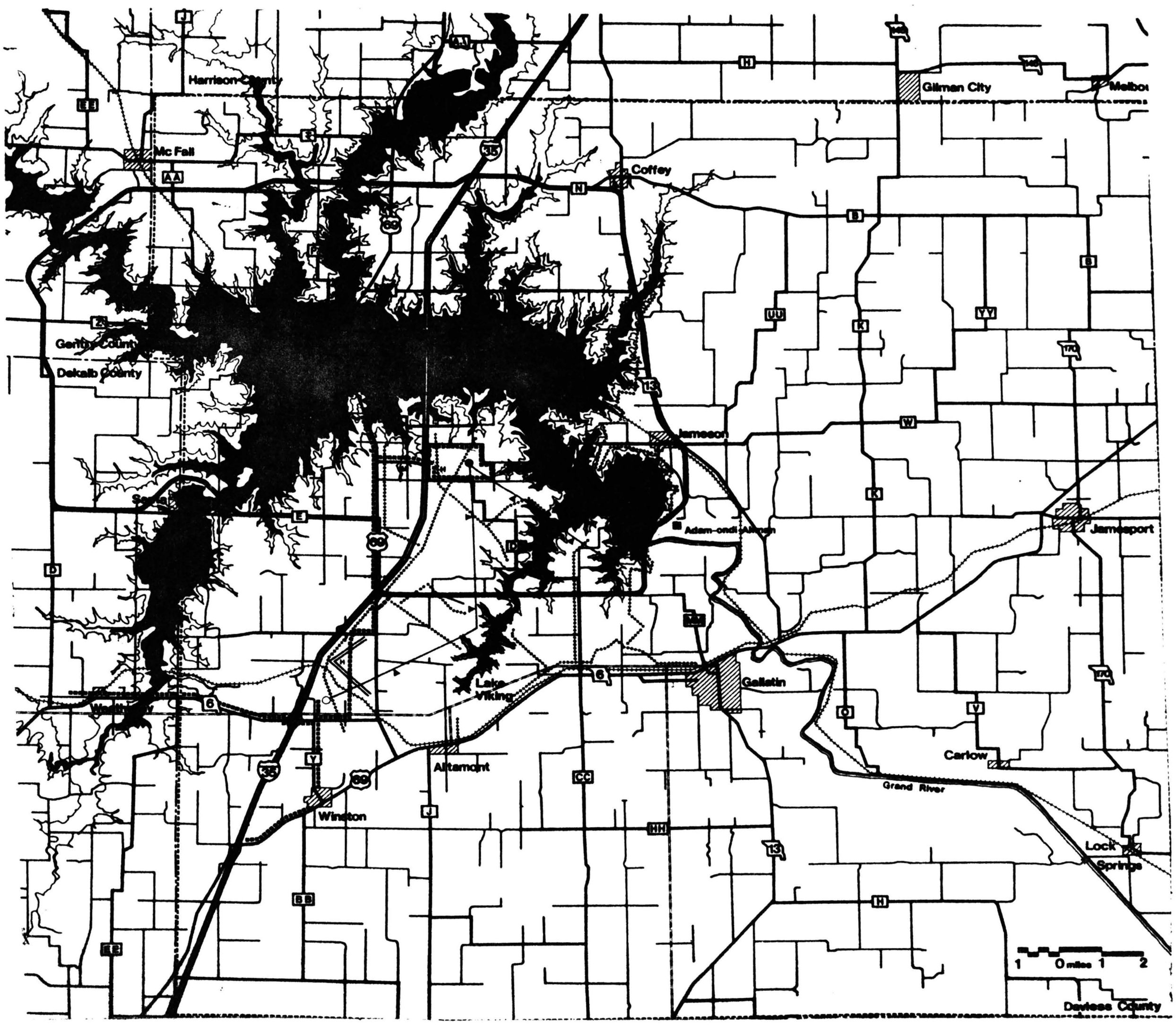
The planners of the Missouri Department of Community Affairs took care to parallel the spirit and intent of the "Housing and Urban Development Act," signed by President Nixon on February 2, 1971, and followed by the President's philosophy expressed in his 1971 State of the Union Address, "I will propose programs to make better use of land and to encourage a balanced national growth--growth that will revitalize our rural heartland and enhance the quality of life throughout America."[1] (p. 10). The planners proposed the New Town of Pattonsburg location as indicated in Map 1.

C. OBJECTIVES

The objective of this study is to plan for the electrical energy and power requirements of the new town of Pattonsburg for that time in its future when it has attained a population of 50,000.

This study will be conducted according to the following outlines:

1. A reasonable planning estimate of the electrical load for the following will be made:
   a. Housing
   b. Industrial
   c. Commercial
   d. Municipal and street lighting



Map 1. The Proposed Location of the Reservoir and New Town of Pattonsburg - Daviess County, Missouri [1] (p. 75).

2. A reasonably accurate estimate of available electrical energy sources close to Pattonsburg will be made. This will be based on:
   a. Electrical energy which can be produced hydraulically by the flow over the dam.
   b. Available additional energy capacity on the surrounding transmission lines.
3. Then, based on the results of 1 and 2:
   a. An estimated distribution layout for the new town of Pattonsburg, and
   b. additional transmission facilities to supply the peak load will be recommended.

II. A REASONABLE PLANNING ESTIMATE OF THE POWER LOAD

A. ESTIMATION OF THE POWER LOAD FOR HOUSING

A part of the total impact of the Pattonsburg reservoir on the surrounding region results from new residential construction stimulated by the reservoir. Included in this construction are permanent, year-round dwellings as well as weekend or vacation residences. Reasonable projections of this type of activity are difficult to make with any degree of reliability without a detailed market study. However, the projections developed for this study were based largely on experience obtained at other reservoirs. This approach has several limitations. Rarely is it possible to identify a situation comparable to the one under study. Each area is different with respect to market characteristics and physical features. Nevertheless, the experience at other reservoirs can provide a basis for judgment.

To predict the numbers of dwelling units established in a community of 50,000 people, the population size is divided by the statistical average of 3.7 people per American family unit. This results in 13,514 dwelling units. Allowance must be made for the impact of the reservoir on weekend leisure living and vacation housing units, and the impact of probable educational institutions (e.g. junior colleges), and industrial parks with their related housing requirements. In accounting for these factors, it would be reasonable to say that the number of dwelling units is equal to 13,514

+ 5 percent for reservoir impact + 2.5 percent for industrial impact + 2.5 percent for the educational institution impact. The summation of the above gives an approximate total of 14,865 units. This figure would include the number of houses, apartments, and mobile homes. Using the 1970 U.S. Bureau of Census Data for Columbia, Missouri, results in:

3,000 units occupied by singles,
5,000 units occupied by two persons,
2,900 units occupied by three persons,
2,100 units occupied by four persons,
1,100 units occupied by five persons, and
765 units will be occupied by six or more persons.

The planning and calculation of the electrical power requirements for the residential areas are based on the following assumptions:

1. All housing units will use conventional or other sources of energy for home heating purposes.
2. All units will be equipped with basic electrical appliances, including light fixtures, all-electric kitchens, and complete or partial home air conditioning.
3. The house living area and the lot width per housing unit will be based on the following scale:

	Living Area	Lot Width (See Table II)
For Singles or Couples	1,200 ft^2/unit	(50-55) feet
For Three or Four Persons	1,600 ft^2/unit	(60-65) feet
For Five or Six Persons	1,800 ft^2/unit	(70-75) feet

Power loads for residential area units can be calculated using values of 50 percent anticipated growth from Table I. These values yield the following results:

(3,000+5,000) single & double units x 6 KVA/unit = 48,000 KVA

(2,900+2,100) three & four units x 8.5 KVA/unit = 42,500 KVA

(1,100+765) five or six units x 9.5 KVA/unit ≃ 17,700 KVA

TOTAL LOAD FOR RESIDENTIAL AREA ≃ 108,200 KVA

Calculation of load requirement, based on the information in Table I, for an anticipated 100 percent growth rate, yields the following results:

8,000 units x 4 KVA/unit = 32,000 KVA

5,000 units x 6 KVA/unit = 30,000 KVA

1,875 units x 6 KVA/unit ≃ 11,200 KVA

TOTAL LOAD FOR RESIDENTIAL AREA ≃ 73,200 KVA

Perhaps, a typical housing unit could be as shown in Figures 1, 2, and 3.

TABLE I

Relationship Between the Initial Noncoincidental Load Per House in KVA and Living Area in Square Feet and Specific Anticipated Load Growth for Use in Estimating the Final Load to be Expected During the Life of the System[13] (p. E151).

Anticipated Growth Rate	House Initially Equipped With	Living Area - Square Feet											
		1000	1200	1500	1900	2300	2700	3100	3500	3900	4300	4700	5000
		NONCOINCIDENT LOAD PER HOUSE - KVA											
100	Basic Appliances, Partially Air-Conditioned	4	4	6	6	-	-	-	-	-	-	-	-
	Basic Appliances, Electric Kitchen Partially Air-Conditioned	4	4	6	6	-	-	-	-	-	-	-	-
50	Basic Appliances, Completely Air-Conditioned	6	6	8	8	10	12	12	12	14	14	18	18
	Basic Appliances, Electric Kitchen Completely Air-Conditioned	6	6	8	10	10	12	14	14	16	16	18	20
25	All Major Appliances, Completely Air-Conditioned	8	8	10	12	12	14	16	16	16	18	20	20
	Gold Medallion (Winter)	18	20	22	24	26	-	-	-	-	-	-	-
	Portable Air Conditioner (ton)	2	2 1/2	3	3 1/2	4	5	5	2 to 3		2 through 5		

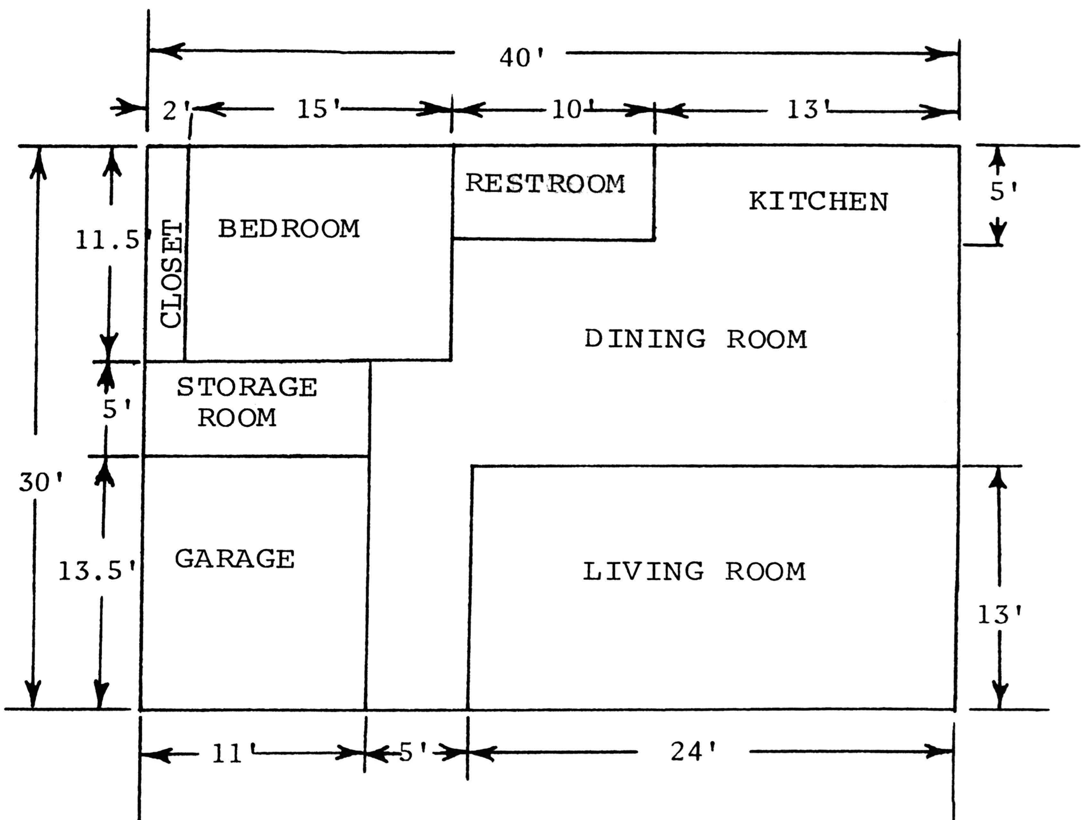


Figure 1. Typical House Used For Singles and Couples

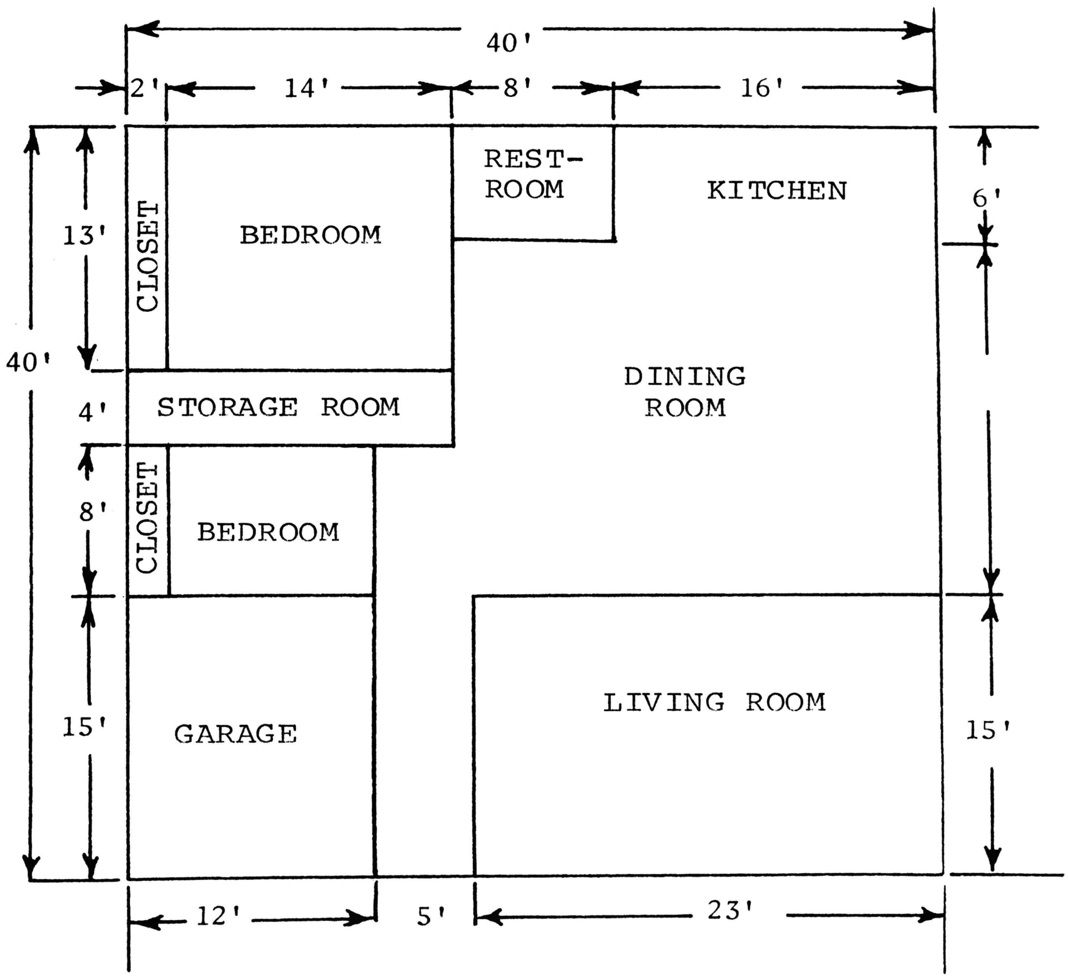


Figure 2. Typical House Used by Three or Four People

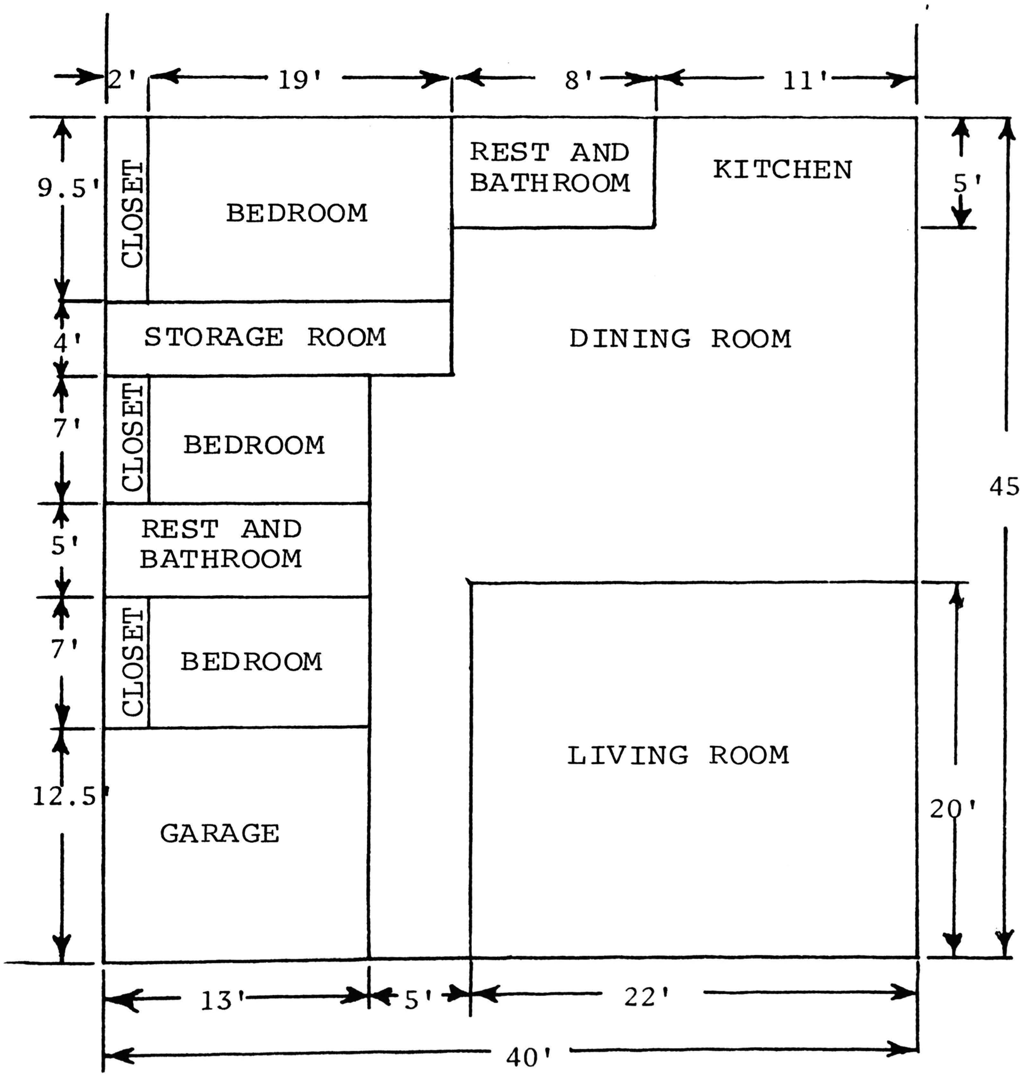


Figure 3. Typical House Used by Five or More People

There is another method of finding the load for a given residential area. This method is normally used to determine the design load when the size of a house or the nature of appliances cannot be determined directly. This method is based on statistical survey analysis. Such a survey was conducted by the Oklahoma Gas and Electric Company. The survey covered statistical load in 50 developments constructed in the Oklahoma City area during 1961, 1962, and 1963. These developments served some 3,467 customers. When the survey was made, it was noted that loads within each development varied widely. It was also noted that loads are independent of location. The survey revealed that homes constructed on 70-foot lots in Norman or Del City, Oklahoma, had the same load characteristics as homes constructed on 70-foot lots in northwest Oklahoma City.

In order to use Table II, the following assumptions were made:

House Occupants	Living Area Sq Ft	Lot Width Ft
Singles and Couples	1,200	50-55
Three or Four People	1,600	60-65
Five or More People	1,800	70-75

Calculation for Residential Area Loads:

8,950 lots	x	4.5 KVA/lots	≃	40,300 KVA
5,700 lots	x	7.0 KVA/lots	=	39,900 KVA
2,240 lots	x	11.0 KVA/lots	≃	24,600 KVA
		TOTAL	≃	104,800 KVA

TABLE II

Relationship Between Lot Width (Feet) and Noncoincident Load Per House (KVA)

I. MAXIMUM. Recommended Design Load for Secondaries

II. Recommended Maximum Design Load Transformer

III. Average. Recommended Minimum Design Load for Transformer

IV. MINIMUM.

LOT WIDTH - FEET

	50-55	60-65	70-75	80-85
	NONCOINCIDENT LOAD PER HOUSE - KVA			
I.	10	12	16	18
II.	4.5	7	11	13
III.	3.8	5	7.4	11
IV.	1.0	1.9	2.8	3.8

B. ESTIMATION OF POWER LOAD FOR INDUSTRY

The industries which are likely to settle in the New Pattonsburg area will, to a large extent, be determined by the percentage growth of industries located in Missouri from 1964-1969.

From community historical accounts, both recent and dated, it can be observed that generally only those communities which have a purpose or reason for existence survive. As economic conditions and trends change, communities must adjust accordingly to serve their residents' new needs, or face stagnation, decline, and eventual extinction. Many towns in rural northwestern Missouri which once served as trade and service centers for agricultural communities have shifted economic bases to survive. Some now serve as educational centers for immediate and surrounding areas, some serve as medical centers by providing hospital facilities and nursing home services, and some towns have come to rely on tourism and recreation. But the most successful transition made by towns willing to change economic bases has been made by those which become small, industrial centers. Many rural communities would hope to attract new industries to locate within their city limits; but industries are highly selective of plant site locations. Towns which cannot provide industrial access and support facilities (e.g. good transportation systems), adequate labor supply, and community services, etc., are not successful in attracting industrial settlements. But for those towns which can provide these needs, towns like the proposed New Pattonsburg, the emerging pattern of industrial establishments is encouraging. American industry is moving into small towns in increasing numbers because of such advantages as available labor at lower wage rates, lower cost sites, and lower taxes. From 1964 to 1969, 53.7 percent of all new plant locations in the State of Missouri were in rural areas outside of standard metropolitan areas of 50,000 population or more, and what is especially encouraging is the fact that these industries have generally projected growth rates during the 1970's which are expected to exceed the national average growth rate of 4.0 percent annually.

In view of New Pattonsburg's proximity, approximately 75 miles from Kansas City, its accessibility via the Interstate, the recreation opportunities at the reservoir and the town's new physical facilities and desirable living environment, it should compete well in attracting industrial settlement. Besides all these advantages, Pattonsburg originally was meant to serve as an attraction for the youth in the area. The following is a listing of medium and light industries typical of those having settled in rural Missouri areas and enjoying a projected growth rate above the national average:

1. Transportation Equipment
2. Lumber and Wood Products
3. Nonelectrical Machinery
4. Fabricated Metal Products

5. Chemical and Allied Products

6. Apparel and Related Products

7. Electrical Machinery

As a basis for calculating the load of such industries located in New Pattonsburg, a prediction should be made of the number of people likely to be employed in the new plants. Data for calculating this prediction is provided in Table III.

Prediction of the number of Industrial Workers by Linear Method

$$y = a + bx$$

y = number of industrial workers

x = population of the city

a and b = constants

n = number of given data sets

$$\Sigma y = aN + b\Sigma x$$

$$\Sigma xy = a\Sigma x + b\Sigma x^2$$

$$3{,}703 = 5a + 26{,}000b$$

$$2{,}467.4\text{x}10^4 = 26{,}000a + 184\text{x}10^6 b$$

$a = 163.229508$

$b = \quad 0.1110327869$

for $x = 50{,}000$

$$y = 163.2295081 + 0.1110327869\text{x}5\text{x}10^4 = 5{,}714.866$$

$$\simeq 5{,}715 \text{ persons}$$

Table IV is a tabulation of calculated results.

Prediction of the Number of Industrial Workers by Log Log Method

TABLE III

Relation of Estimated Number of Establishments
to Alternative Population Levels[1] (p. 37)

Industry	Population of the Town				
Manufacturing	1,000	3,000	5,000	7,000	10,000
Employees	190	524	795	1,001	1,193
Employees/Establishment	50	50	50	50	50
Establishments	4	10	16	20	24

TABLE IV

Calculated Parameters Required in the Prediction of Industrial Workers by Linear, Log Log, and Quadratic Method

x	y	xy	x^2	y^2	log x
1,000	190	1.9×10^5	10^6	36,100	3.0
3,000	524	1,572,000	9×10^6	274,576	3.47712
5,000	795	3,975,000	25×10^6	632,025	3.69897
7,000	1,001	7,007,000	49×10^6	1,002,001	3.845098
10,000	1,193	11,930,000	100×10^6	1,423,249	4.0
Σ26,000	3,703	24,674,000	184×10^6	3,367,951	18.021188

log y	$(\log x)^2$	$\log y^2$	log x log y	x log y
2.27875	9.0	4.557507	6.83625	2,278.75
2.71933	12.09037	5.4386626	9.45543673	8,157.99
2.900367	13.682379	5.8007343	10.72837052	14,501.835
3.000434	14.7847789	6.000868	11.53696277	21,003.038
3.0766404	16.0	6.15328089	12.3065616	30,766.404
Σ13.9755214	65.5575279	27.95105308	50.86358162	76,708.017

x^2y	x^3	x^4
19×10^7	1×10^9	1×10^{12}
$4,716 \times 10^6$	27×10^9	81×10^{12}
$19,875 \times 10^6$	125×10^9	625×10^{12}
$49,049 \times 10^6$	343×10^9	$2,401 \times 10^{12}$
$119,300 \times 10^6$	$1,000 \times 10^9$	$10,000 \times 10^{12}$
$\Sigma 193,130 \times 10^6$	$1,496 \times 10^9$	$13,108 \times 10^{12}$

TABLE IV

Calculated Parameters Required in the Prediction of Industrial Workers by Linear, Log Log, and Quadratic Method (continued)

x^2 log y	log x^2	$(\log y)^2$
2.278750×10^6	6.0	5.192701562
24.473970×10^6	6.954242511	7.394755642
72.509175×10^6	7.397940007	8.412128739
147.021266×10^6	7.690196082	9.00260419
307.664040×10^6	8.0	9.465716143
$\Sigma 553.950628 \times 10^6$	36.04234343	39.46790627

$$y = ax^b$$

$$\log y = \log a + b\log x$$

$$\Sigma\log y = N\log a + b\Sigma\log x$$

$$\Sigma\log x\log y = \log a\Sigma\log x + b\Sigma(\log x)^2$$

$$13.9755214 = 5\log a + 18.021188b$$

$$50.8635816 = 18.021188\log a + 65.5575176b$$

$a = 0.7253939014$ $\qquad b = 0.8147084719$

$x = 50{,}000$ $\qquad y = 0.7253939014(50{,}000)^{0.8147084719}$

$$y \simeq 4{,}885.00 \text{ persons}$$

The average result of the two calculated predictions is:

(4,885 + 5,715) persons ÷ 2 = 5,300 persons

Population predictions made by the semi-log and quadratic methods gave inconsistent and unreasonable results. For calculating the industrial loads, the following assumptions are made:

1. The average employment figure of 50.5 employees per new plants locating in communities outside Missouri's metropolitan areas is used as a basis for Pattonsburg.
2. The number of industrial plants to be located in such towns as New Pattonsburg depends on projected annual growth for 1970-80. A higher percentage of those industries with higher projected annual growth rates will have a greater number of plants. The number of plants is derived by taking its percentage of the total projected growth rate multiplied by 100.

Calculation of the number of plants in New Pattonsburg:

5,300 persons ÷ 50.5 persons/plant ≃ 104 plants

The number of plants for different industries:

Industry	Number of Plants	Projected Annual Growth 1970-1980
Transportation Equipment	17	6.0 percent
Lumber and Wood Products	13	4.5 percent
Nonelectrical Machinery	13	4.9 percent
Fabricated Metal Products	12	4.4 percent
Chemical and Allied Products	18	6.5 percent
Apparel and Related Products	13	4.7 percent
Electrical Machinery	18	6.6 percent

Calculations for industrial loads are based finally on data given by Union Electric in Tables V, VI, and VII. Table VI is based on data in Table V, and lists the average consumption of energy per plant from 1969 to 1973.

Table VII lists the average, highest consumption of electrical energy per plant and its equivalent in KW units.

Transportation Equipment

17 plants x 1,947.00 KW/plant ≃ 33,100.00 KW

Lumber and Wood

13 plants x 96.00 KW/plant = 1,248.00 KW

Nonelectrical Machinery

13 plants x 162.00 KW/plant = 2,106.00 KW

Fabricated Metal Products

12 plants x 248.00 KW/plant = 2,976.00 KW

TABLE V

Data Furnished by Union Electric Company Shows for Each Type of Industry
Consumption of Electrical Energy for One-Year Period
and the Number of Industries They Serve

		1969		1970	
Industry	SIC Codes	Number of Customers	KWh Used	Number of Customers	KWh Used
Apparel and Related Products	23	12	8,134,000	14	8,242,000
Lumber and Wood Products	24	7	5,970,000	8	4,020,000
Chemical and Allied Products	28	74	876,218,000	77	888,386,000
Fabricated Metal Products	34	95	191,382,000	99	200,643,000
Machinery, Except Electrical	35	66	81,897,000	69	81,243,000
Electrical Machinery	36	45	173,890,000	47	174,235,000
Transportation Equipment	37	54	773,947,000	57	741,842,000

TABLE V

Data Furnished by Union Electric Company Shows for Each Type of Industry
Consumption of Electrical Energy for One-Year Period
and the Number of Industries They Serve (Continued)

Industry	SIC Codes	1971 Number of Customers	1971 KWh Used	1972 Number of Customers	1972 KWh Used
Apparel and Related Products	23	13	8,828,000	12	9,851,000
Lumber and Wood Products	24	10	6,058,000	9	7,129,000
Chemical and Allied Products	28	77	906,403,000	80	886,799,000
Fabricated Metal Products	34	105	208,089,000	107	232,092,000
Machinery, Except Electrical	35	67	79,780,000	68	86,610,000
Electrical Machinery	36	47	173,826,000	46	177,067,000
Transportation Equipment	37	56	764,337,000	56	786,227,000

TABLE V

Data Furnished by Union Electric Company Shows for Each Type of Industry Consumption of Electrical Energy for One-Year Period and the Number of Industries They Serve (Continued)

1973

Industry	SIC Codes	Number of Customers	KWh Used
Apparel and Related Products	23	11	9,356,000
Lumber and Wood Products	24	9	7,558,000
Chemical and Allied Products	28	80	928,440,000
Fabricated Metal Products	34	126	257,380,000
Machinery, Except Electrical	35	66	93,660,000
Electrical Machinery	36	45	182,394,000
Transportation Equipment	37	46	784,615,000

TABLE VI

Relationship Between the Industries and Average Consumption of Electrical Energy KWh/Plant/Year

Industry	1969 Number of Customers	1969 Average KWh Used Per Customer	1970 Number of Customers	1970 Average KWh Used Per Customer
Apparel and Related Products	12	677,800	14	588,700.00
Lumber and Wood Products	7	852,900.00	8	502,500.00
Chemical and Allied Products	74	11,840,800.00	77	11,537,500.00
Fabricated Metal Products	95	2,014,500.00	99	2,026,700.00
Machinery, Except Electrical	66	1,240,900.00	69	1,177,400.00
Electrical Machinery	45	3,864,200.00	47	3,707,100.00
Transportation Equipment	54	14,332,400.00	57	13,014,800.00

TABLE VI

Relationship Between the Industries and Average Consumption of Electrical Energy KWh/Plant/Year (Continued)

	1971		1972	
Industry	Number of Customers	Average KWh Used Per Customer	Number of Customers	Average KWh Used Per Customer
Apparel and Related Products	13	679,100.00	12	820,900.00
Lumber and Wood Products	10	605,800.00	9	792,100.00
Chemical and Allied Products	77	11,771,500.00	80	11,085,000.00
Fabricated Metal Products	105	1,981,800.00	107	2,169,000.00
Machinery, Except Electrical	67	1,190,700.00	68	1,273,600.00
Electrical Machinery	47	3,698,400.00	46	3,849,300.00
Transportation Equipment	56	13,648,900.00	56	14,039,800.00

TABLE VI

Relationship Between the Industries and Average Consumption of Electrical Energy KWh/Plant/Year (Continued)

1973

Industry	Number of Customers	Average KWh Used Per Customer
Apparel and Related Products	11	850,500.00
Lumber and Wood Products	9	839,800.00
Chemical and Allied Products	80	11,605,500.00
Fabricated Metal Products	126	2,042,700.00
Machinery, Except Electrical	66	1,419,000.00
Electrical Machinery	45	4,053,200.00
Transportation Equipment	46	17,056,800.00

TABLE VII

Relationship Between the Industries and Their Highest Consumption of Electrical Energy in KWh and KW Units (During One-Year Period)

Industry	Year of Peak Consumption	KWh in Peak Year of Five-Year Period	KW Used*
Apparel and Related Products	1973	850,500.00	97.00
Lumber and Wood Products	1973	839,800.00	96.00
Chemical and Allied Products	1969	11,840,800.00	1,351.00
Fabricated Metal Products	1972	2,169,000.00	248.00
Machinery, Except Electrical	1973	1,419,000.00	162.00
Electrical Machinery	1973	4,053,000.00	462.00
Transportation Equipment	1973	17,056,800.00	1,947.00

* Divided KWh/Year by 8,760 Hours/Year

Chemical and Allied Products

$18 \text{ plants} \times 1{,}351.00 \simeq 24{,}320.00 \text{ KW}$

Apparel and Related Products

$13 \text{ plants} \times 97.00 = 1{,}201.00 \text{ KW}$

Electrical Machinery

$18 \text{ plants} \times 462.00 = 8{,}316.00 \text{ KW}$

TOTAL KW USED BY THE SEVEN SUGGESTED INDUSTRIES $\simeq$ 73,390 KW

$$\frac{KW}{KVA} = \cos x = .8$$

$$73{,}390.00 \text{ KW} \div 0.8 \frac{KW}{KVA} \simeq 91{,}740.00 \text{ KVA} \simeq 92{,}000 \text{ KVA}$$

C. ESTIMATION OF THE LOADS FOR THE COMMERCIAL AREA

It is very difficult to estimate the businesses that are going to move into the New Pattonsburg area, and comply with and fulfill the needs of that community.

From a statistical point of view, it is known, however, that for August, 1972, in the west north central part of the United States, approximately 21.27 percent of the electrical energy is used for commercial purposes.

D. ESTIMATION OF LOAD FOR MUNICIPAL POWER AND STREET LIGHTING

First consideration is given to the load requirements of the public institutions serving the New Pattonsburg area. These institutions include:

1. United States Department of Agriculture
2. United States Department of the Interior
3. Missouri Geological Survey
4. Missouri State Highway Department
5. Missouri State Highway Patrol
6. City of Pattonsburg - City Hall
7. Pattonsburg Public Utilities
8. Pattonsburg Power Company
9. Pattonsburg Telephone Company
10. Pattonsburg Cable TV
11. The Numerous Churches
12. United States Department of Health, Education, and Welfare
13. Social Security
14. United States Department of Defense
15. Internal Revenue Service
16. United States Post Office
17. Community Colleges and Technical Schools
18. Elementary, Junior High, and Senior High Schools
19. Hospitals (Clinic, Diagnostic, and Mental Health)

In order to plan the electrical load for the above mentioned public facilities, a survey of the City of Rolla, Missouri, was conducted. Rolla's highest power consumption for a single month for the 1973, 12-month period was found to be 1,474,470 KWh. On the basis of population, the consumption for Pattonsburg could be expected to be:

$$\frac{50{,}000 \text{ population of New Pattonsburg}}{14{,}000 \text{ population of Rolla}}(1{,}474{,}470)\text{KWh} \simeq$$

$$5{,}266{,}000 \text{ KWh for one month.}$$

$$5{,}265{,}000 \text{ KWh/month} \times \frac{1 \text{ month}}{30 \text{ days}} \times \frac{1 \text{ day}}{24 \text{ hours}} \simeq 7{,}314.00 \text{ KW}$$

$$\cos \psi = \frac{\text{KW}}{\text{KVA}} = .8$$

$$7{,}314.00 \text{ KW} \div .8 \frac{\text{KW}}{\text{KVA}} \simeq 9{,}142.00 \text{ KVA}$$

A city with a population of 50,000 requires 1,368 KVA to power the water treatment plant (assuming primary and secondary treatment). The same city's sewer treatment plant (with primary and secondary treatment) draws 3,500 KVA.

Thus, the total demand load for such a community's public facilities would equal 9,142.00 KVA + 1,368 KVA + 3,500 KVA = 14,010.00 KVA.

The desirability of roadway and street lighting installation in terms of increased driver safety and comfort has been recognized, and the objectives of street and highway lighting are as follows: Crime reduction, civic improvement, and traffic safety.

The lighting arrangement for a given roadway is influenced by several factors: The dimensions of the roadway, the physical characteristics of the lighting equipment, and the amount and distribution of light cast on the roadway.

The lighting of the future city of Pattonsburg is planned with respect to the lumens (per square foot) requirement of the different parts of the city, the classification of the areas of the city (VIZ. downtown area, intermediate area, and the outlying area), and the classification of roadways, (VIZ. major, collector, local expressway, and freeway). Classifications of the areas of the city are defined as follows:[13] (p. E904).

1. Downtown - "That portion of the streets located in a business or industrial development where ordinarily there are large numbers of pedestrians and a heavy demand for parking space during periods of peak nighttime traffic or a sustained high pedestrian volume and a continuously heavy demand for off-street parking space during business and industrial employment hours."

2. Intermediate - "That portion of the streets located outside of the downtown area, but generally within the zone of influence of a business or industrial development, characterized often by a moderately heavy nighttime pedestrian traffic and a somewhat lower parking turnover than is found in a downtown area."

3. Outlying - "That portion of the streets located in a residential development, or a mixture of residential and commercial establishments, characterized by few pedestrians and a low parking demand or turnover."

Classifications of the roadways of the city are defined as follows:[13] (p. E904).

1. Major - "Part of the roadway system that serves as the principal network for through traffic flow. They should connect areas of principal traffic generation and important rural highways entering the city.

2. Collector - "The distributor and collector roadways serving traffic between major arterial and local roadways. Roadways used mainly for traffic movement within residential, commercial, and industrial areas."

3. Local - "Roadways used primarily for direct access to residential, commercial, industrial, or other abutting property. This does not include roadways carrying through traffic because long local roadways will generally be divided into short sections by collector roadway systems."

4. Expressway - "A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at intersections."

5. Freeway - "A divided arterial highway with full control of access and with no crossings at grade."

The street and roadway lighting of New Pattonsburg was planned in accordance with federal and state government regulations which establish criteria for lighting intensities of public areas and roadways. These requirements, along with area classification and roadway classification, are tabulated in Table VIII.

The following road and street distances are measured from a map prepared by the planners of the future new town:

Residential Streets	- 274,560 feet = 52 miles
Industrial Park Streets	- 12,870 feet = 2.43 miles
Commercial Area Streets	- 18,678 feet = 3.53 miles
Public Facility Roadways	- 34,320 feet = 6.50 miles
Highways	- 47,520 feet = 9 miles

TABLE VIII

Breakdown of Illumination Requirements for Roadways in Varying Urban Area Locations[13] (p. E904).

(lumens per square foot intensity)

	Area Classification		
	Downtown	Intermediate	Outlying
Major	2.0	1.2	0.9
Collector	1.2	0.9	0.6
Local	0.9	0.6	0.2
Expressways			
at interchanges	2.0	2.0	1.4
between interchanges	2.0	1.4	1.0

The planned width of the New Pattonsburg streets are as follows:

Residential Streets	-	60 feet
Public Facility Streets	-	60 feet
Commercial Area Streets	-	80 feet
Highway Commercial Streets	-	100 feet
Industrial Park Roadways	-	100 feet

The calculations for planning the lighting requirements of the different parts of the city were made as follows:

1. Residential streets are classified as belonging to area of the city, outlying, the roadway classification is local. From Table VIII, the lumens per square foot requirement is .2.

Illumination of these streets can be accomplished with a light source of the following type:

"11,500 lumen mercury vapor luminaire, 242,098 light distribution - Type II

Two side spacing, mounted 25 feet high with 4 foot curb overhang."[13] (p. E906).

$$S = \frac{L \times u \times F_1 \times F_2}{(Ft\text{-}c) \times W}$$

S = luminaire spacing in feet

L = bare lamp initial lumen rating

u = coefficient of utilization

F_1 = lamp maintenance factor. For mercury = .9

F_2 = luminaire maintenance factor. For mercury = .85

(Ft-c) = measurement of average light level on the roadway in lumens per square feet (foot-candle)

W = the width of the street in feet

The coefficient of utilization is determined by using Figure 4.

$$\text{Ratio} = \frac{\text{Transverse Width (street or house side)}}{\text{Luminaire Mounting Height}}$$

u_1 = coefficient of utilization for street side

u_2 = coefficient of utilization for house side

$$\text{Ratio for street side} = \frac{60 \text{ feet} - 4 \text{ feet}}{25 \text{ feet}} = 2.2$$

$$u_1 = .45$$

$$\text{Ratio for house side} = \frac{4 \text{ feet}}{25 \text{ feet}} = .16$$

$$u_2 = .02$$

The total coefficient of utilization $= u_1 + u_2 = .02 + .45 = .47$

$$S = \frac{11{,}500 \times .47 \times .9 \times .85}{.2 \times 60} = 345 \text{ feet}$$

Total number of mercury vapor lights needed for the residential area equals:

$$\frac{274{,}560 \text{ feet}}{345 \text{ feet}} \simeq 796 \text{ lamps}$$

Mercury lights at .556μ wavelength

One Watt = 621 lumens

Efficiency Rating 50 ~ 60

$$\frac{11{,}500 \text{ lumens}}{621 \frac{\text{lumens}}{\text{watt}}} = 18.52 \text{ watts}$$

$$\text{Input power for each lamp} = \frac{18.52 \text{ watts}}{.50} = 37 \text{ watts}$$

Total power for lighting of residential streets =

$$796 \text{ lamps} \times \frac{37 \text{ watts}}{\text{lamp}} = 29{,}452 \text{ watts}$$

$$\cos x = \frac{KW}{KVA} = .8$$

$$29.452 \text{ KW} \div .8 \frac{KW}{KVA} \simeq 37.00 \text{ KVA}$$

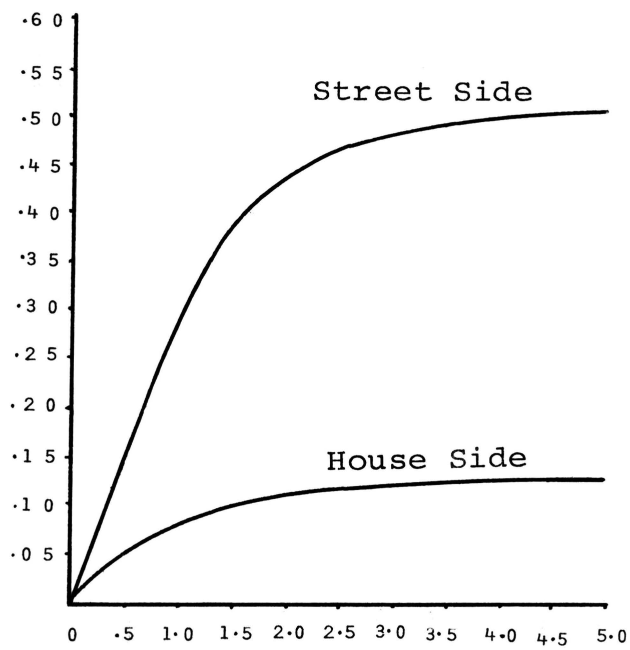


Figure 4. Utilization Curve Used to Determine the Coefficient of Utilization

2. Public facility streets are classified as belonging to the intermediate area and their roadway classification is Major.

From Table VIII, lumen per square feet requirement is 1.2, and for the lighting of these streets, a lamp of the following classification would be used:

"40,000 lumen mercury vapor luminaire, 242,116 light distribution - Type IV

Two side spacing, mounted 30 feet high with a 4 foot curb overhang."[13] (p. E906).

From Table IX, the distance between two poles is 180 feet.

$$\text{Number of lights} = \frac{34{,}320 \text{ feet}}{180 \text{ feet}} = 191 \text{ lamps}$$

$$\frac{40{,}000 \text{ lumens}}{621 \text{ lumens/watt}} = 64.41 \text{ watts}$$

$$\text{Input power for each lamp} = \frac{64.41 \text{ watts}}{.50} = 128.90 \text{ watts}$$

$$\text{Total input power needed} = 128.90 \text{ watts/lamp} \times 191 \text{ lamps} = 24{,}620.00 \text{ watts}$$

$$\text{Power factor} \simeq \cos x = \frac{KW}{KVA} = 0.8$$

$$24.62 \text{ KW} \div 0.8 \frac{KW}{KVA} \simeq 31.00 \text{ KVA}$$

3. Commercial streets are classified as part of the downtown urban area, and their roadway classification is Major. From Table VIII, lumens per square feet requirement is 2.

TABLE IX

Relation Between Street Width and Lumens Per Square Foot for a 40,000 Lumen Mercury Vapor Luminaire Lamp With Two Side Spacing Mounted 30 Feet High With 4 Foot Curb Overhang[13] (p. E906).

Units Spac-Ft	Street Widths 20	30	40	50	60	70	80	90	100
100'	#3.06	2.85	2.67	2.44	2.19	1.96	1.79	1.63	1.49
	1.95:1	1.93:1	2.24:1	2.2:1	3.32:1	4.08:1	5.42:1	5.82:1	6.48:1
110'	2.78	2.59	2.43	2.22	1.99	1.78	1.63	1.48	1.36
	2.11:1	2.07:1	2.31:1	2.22:1	3.21:1	4.05:1	5.62:1	6.17:1	7.16:1
120'	2.55	2.38	2.23	2.04	1.82	1.63	1.49	1.36	1.24
	2.38:1	2.22:1	2.42:1	2.29:1	3.19:1	4.08:1	6.21:1	7.16:1	8.27:1
130'	2.35	2.19	2.05	1.88	1.68	1.51	1.38	1.25	1.15
	2.47:1	2.31:1	2.44:1	2.32:1	3:1	3.97:1	6:1	6.94:1	7.67:1
140'	2.18	2.04	1.91	1.74	1.56	1.40	1.28	1.16	1.07
	2.63:1	2.46:1	2.48:1	2.38:1	2.89:1	3.78:1	6.1:1	7.25:1	7.64:1
150'	2.04	1.90	1.78	1.63	1.46	1.31	1.19	1.08	.99
	2.72:1	2.53:1	2.54:1	2.43:1	2.70:1	3.64:1	5.67:1	7.2:1	7.62:1
160'	1.91	1.78	1.67	1.53	1.37	1.22	1.12	1.02	.93
	2.85:1	2.66:1	2.57:1	2.51:1	2.63:1	3.59:1	5.89:1	7.29:1	7.75:1
170'	1.80	1.68	1.57	1.44	1.29	1.15	1.05	.96	.88
	3.0:1	2.9:1	2.75:1	2.57:1	2.63:1	3.38:1	5.53:1	6.86:1	7.33:1

\# The top figures are average maintained horizontal foot-candle levels (lumens per square foot). The lower figures represent the ratio of contrast between the average foot-candle and the minimum foot-candle level.

TABLE IX

Relation Between Street Width and Lumens Per Square Foot for a 40,000 Lumen Mercury Vapor Luminaire Lamp With Two Side Spacing Mounted 30 Feet High With 4 Foot Curb Overhang[13] (p. E906). (Continued)

Units Spac-Ft	Street Widths 20	30	40	50	60	70	80	90	100
180'	1.70 3.18:1	1.58 3.16:1	1.48 2.96:1	1.36 2.72:1	1.21 2.63:1	1.09 3.21:1	.99 5.21:1	.90 6.43:1	.83 6.92:1
190'	1.61 3.93:1	1.50 4.75:1	1.40 3.50:1	1.28 3.2:1	1.15 3.38:1	1.03 3.32:1	.94 4.95:1	.85 6.07:1	.78 6.5:1
200'	1.53 5.28:1	1.42 4.9:1	1.33 4.59:1	1.22 4.21:1	1.09 3.75:1	.98 3.38:1	.89 4.68:1	.81 5.79:1	.74 6.17:1
210'	1.45 6.04:1	1.36 5.44:1	1.27 5.08:1	1.16 4.64:1	1.04 4.16:1	.93 3.72:1	.85 4.72:1	.77 5.5:1	.71 5.92:1
220'	1.39 7.32:1	1.29 6.14:1	1.21 5.76:1	1.11 5.29:1	.99 4.71:1	.89 4.68:1	.81 4.5:1	.74 5.29:1	.68 5.67:1
230'	1.33 8.31:1	1.24 6.89:1	1.16 6.44:1	1.06 5.89:1	.95 5.28:1	.85 4.72:1	.78 5.2:1	.70 5.00:1	.65 5.42:1
240'	1.27 9.77:1	1.19 9.15:1	1.11 8.54:1	1.02 7.85:1	.91 7:1	.81 6.23:1	.74 5.69:1	.68 5.83:1	.62 5.64:1

The top figures are average maintained horizontal foot-candle levels (lumens per square foot). The lower figures represent the ratio of contrast between the average foot-candle and the minimum foot-candle level.

The lighting of this part of the city could be accomplished with lamps of the following type: "40,000 lumens mercury vapor luminaire, 242,116 light distribution - Type IV

Two side spacing mounted 30 feet high with 4 foot curb overhang."

For finding the coefficient of utilization, Figure 4 is used:

$$\text{Ratio for street side} = \frac{80 \text{ feet} - 4 \text{ feet}}{30 \text{ feet}} = 2.53$$

$$u_1 = .47$$

$$\text{Ratio for house side} = \frac{4 \text{ feet}}{30 \text{ feet}} = .133$$

$$u_2 = 0.015$$

$$u = u_1 + u_2 = 0.015 + 0.47 = .485$$

$$S = \frac{40{,}000 \times 0.485 \times .9 \times .85}{2 \times 80} = 92.75 \text{ feet}$$

$$\text{Total number of lamps needed} = \frac{18{,}678 \text{ feet}}{92.75 \text{ feet}} = 201.36 \simeq 202$$

$$40{,}000 \text{ lumens} \div 621 \text{ lumens/watt} = 64.41 \text{ watts}$$

$$\text{input power} = \frac{64.412 \text{ watts}}{.5} \simeq 128.80 \text{ watts}$$

$$\text{Total power needed} = 128.80 \text{ watts} \times 202 \simeq 26{,}020.00 \text{ watts}$$

$$26.02 \text{ KW} \div 0.8 \frac{\text{KW}}{\text{KVA}} = 32.52 \text{ KVA}$$

4. Highways which pass through the city areawise, are classified as portions of the intermediate urban area; the roadway classification is Expressway. From Table VIII, lumens per square foot requirement is 2.0, and for lighting the highways, a light source with the following specification could be used:

"40,000 lumens mercury vapor luminaire, 242,116 light distribution - Type IV
Two side spacing, mounted 30 feet high with 4 foot curb overhang."

$$u = .505$$

$$S = \frac{40,000 \times .505 \times .9 \times .85}{2 \times 100} = 77.26 \text{ feet}$$

Number of lamps needed = 47,520 feet ÷ 77.26 feet ≃ 615 lamps

40,000 lumens ÷ 621 lumens/watt = 64.41 watts

$$\text{Input power} = \frac{64.41 \text{ watts}}{.5} \simeq 128.80 \text{ watts}$$

Total power needed = 615 lamps x 128.80 watts/lamp ≃ 79,220.0 watts

$$\frac{KW}{KVA} = .8 = \text{power factor}$$

79.22 KW ÷ .8 KW/KVA = 99.00 KVA

5. Industrial park roadways, areawise, are classified as downtown areas, and the roadway classification is Major. From Table VIII, lumens per square foot requirement is 2.0, and for lighting streets of this part of the city, a lamp with the following specification would be applicable:

"40,000 lumens mercury vapor luminaire, 242,116 light distribution - Type IV
Two side spacing, mounted 30 feet high with 4 foot curb overhang."

Calculations are as follows:

$$u = .505$$

$$S = \frac{40{,}000 \times .505 \times .9 \times .85}{2 \times 100} = 77.26 \text{ feet}$$

Number of lamps needed = 12,870 feet ÷ 77.26 feet ≃ 167 lamps

40,000 lumens ÷ 621 lumens/watt = 64.41 watts

$$\text{Input power} = \frac{64.41 \text{ watts}}{.5} \simeq 128.80 \text{ watts}$$

Total power needed = 167 x 128.80 watts ≃ 21,510.00 watts

$$\frac{KW}{KVA} = \text{power factor} = .8,$$

$$21.51 \text{ KW} \div .8 \frac{KW}{KVA} \simeq 26.90 \text{ KVA}$$

6. Calculation of total power needed for lighting the streets of the city:

Residential Streets	- 37.00 KVA
Public Facility Streets	- 31.00 KVA
Commercial Streets	- 32.52 KVA
Highways	- 99.00 KVA
Industrial Park Roadways	- 26.90 KVA

The sum total power needed to light the streets of the city ≃ 226.00 KVA. Allowance must be made for lighting requirements at city street intersections. From information in Table VIII, the lumens per square foot requirement is 2, and to allow a sufficient factor of safety for overall plan, extra streetlights at intersections, traffic signals, etc., an additional 5 KVA should be added to the above calculated sum.

Thus, the total power needed for complete lighting of city thoroughfares = 5 KVA + 226.00 KVA = 231.00 KVA.

III. ESTIMATE OF AVAILABLE ELECTRICAL ENERGY OF ALL SOURCES

A. THE DAM

The Grand River, which drains an area of 5,030.6 square miles in Missouri, flows toward the southeast and into the Missouri River. The river provides a source of recreation as well as a source of hydroelectric power when channeled through turbines at a dam.

The discharge of the river, plus precipitation less evaporation from the lake, less evaporation and transpiration from the land area, less infiltration into the soil and the reservoir bed, less the domestic and industrial usage by the New Town of Pattonsburg, equals the remaining amount of water available for power.

Calculation of the potential hydroelectric power available from the Grand River is based on 12 recorded, consecutive annual average discharge rates of the river. The information regarding recorded river discharge rates is provided from data taken by the U.S. Geological Survey near Gallatin, Missouri, as shown in Table X.

An average annual evaporation figure for the area is 39 inches, as shown on the map. Average annual precipitation for the area is 36 inches, 70 percent of which occurs from April to September. The average annual runoff is about 6 inches. The soil survey for Daviess County, Missouri, shows that the proposed reservoir lakebed and surrounding land is very impermeable.

TABLE X

Relationship Between Annual Monthly Mean Discharge of the Grand River Near Gallatin, Missouri, in Cubic Feet Per Second [7, 8, 9]

Year	Discharge in Cubic Feet Per Second											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961	121	1,399	5,280	3,139	1,551	1,073	648	488	6,768	2,769	7,268	576
1962	1,537	6,196	4,022	494	1,523	1,227	346	203	178	855	218	88.5
1963	65.6	256	3,263	559	1,606	146	444	100	110	49.2	58.2	21.3
1964	25.8	44.1	85.4	1,125	743	4,537	744	85	2,260	117	235	243
1965	1,201	1,117	3,427	3,221	1,181	1,013	3,691	175	4,800	504	248	807
1966	509	428	299	200	793	1,525	400	218	54.9	184	37.4	328
1967	61.9	177	197	1,684	495	8,492	888	86.1	49.9	562	265	113
1968	303	220	141	2,262	361	198	521	217	40.2	371	99.7	206
1969	774	1,091	630	2,643	2,438	1,102	4,824	326	2,909	1,144	978	202
1970	192	212	251	2,405	2,405	1,647	100	760	3,759	1,529	1,131	740
1971	225	2,936	1,383	387	623	124	114	56.6	40.6	43.8	686	722
1972	153	199	293	645	3,718	478	626	276	1,054.2	102.2	1,985.8	1,124
MEAN	430	1,189.6	1,605	1,563.6	1,453	1,796.8	1,112.1	249.2	1,835.3	685.8	1,100.8	406.3

This is revealed by soil composition analysis:

Subsurface Level	Soil Type
First 1-10 feet	silt
Second 10-20 feet	till glacial
Third 10-20 feet	shale
Fourth 10-20 feet	limestone

Following the fourth 10-20 feet are alternate layers of shale and limestone.

By virtue of such soil composition, the infiltration factor of the lakebed could be neglected though some slight measure of infiltration should be expected for the first few years until soil saturation is achieved.

Based on the figures in Table X, the average discharge of the Grand River for 12 consecutive years is 1,119 cubic feet per second.

Calculations can now be made of the amount of water needed by the town for domestic and industrial use on the average basis of 150 gallons/capita/day = 150 gpcd

150 gpcd x 50,000 c = 7,500,000 gallons per day

$$\frac{7{,}500{,}000}{1{,}000\ 000} \text{million g/day} \times 1.547 \ \frac{\text{cfs}}{\text{million g/day}} = 11.6 \text{ cfs}$$

The net amount of water available for power

= 1,119 - 11.6 = 1,107.4 cfs

On the basis of an elevation contour map of the New Pattonsburg area, the reservoir's high pool elevation point will be 836 feet, and the low pool point will be 811 feet. This allows a 25 foot fluctuation in reservoir level, insuring sufficient quantity of water for hydroelectricity production in the event of a dry season.

Calculation for horsepower produced at the dam:

at e efficiency $$HP = \frac{Q\gamma H}{550}(e)$$

where Q = flow in cubic feet per second

$\gamma = 62.4\ \text{lb/ft}^3$

H = head in feet

HP = horsepower

e = efficiency $\rightarrow$ losses - hydraulic
mechanical
electrical

$$HP = 33{,}000\ \frac{\text{ft - lb}}{\text{min}} = \frac{33{,}000}{60}\ \frac{\text{ft - lb}}{\text{sec}} = 550\ \frac{\text{ft - lb}}{\text{sec}}$$

$$HP = \frac{1{,}107.4\ \text{ft}^3/\text{sec} \times 62.4\ \text{lb/ft}^3 \times 91\ \text{ft}}{550\ \frac{\text{ft - lb}}{\text{sec}}}(e)$$

$$= 11{,}433.2(e)\ \text{horsepower}$$

It can be reasonably assumed that the type of turbine used for hydroelectricity production will be either Francis, Propeller, or Kaplan type. Figure 5 gives efficiency ratings for these types of turbines. An average efficiency of 85 percent is assumed for this installation which is dependent on the flow of the stream with little storage capacity available.

Calculation for KW output:

$$HP = 11{,}433.2\ HP \times .85 = 9{,}718.22\ HP$$

$$1\ HP = .746\ KW$$

$$9{,}718.22\ HP \times .746\ \frac{KW}{HP} \simeq 7{,}250\ KW$$

$$\frac{KW}{KVA} = \cos x = .85$$

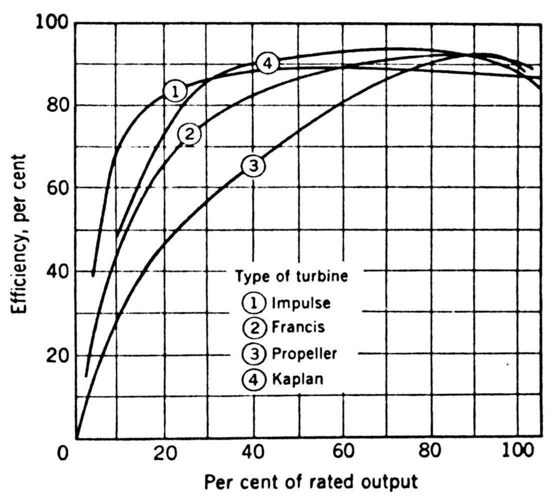


Figure 5. Relationship Between Percent Efficiency and Percent Rated Output for Impulse, Francis, Propeller, and Kaplan Turbines[10] (p. 335).

$$7{,}250 \text{ KW} \div .85 \frac{\text{KW}}{\text{KVA}} = 8{,}529.00 \text{ KVA}$$

The average power for 24 hours operation would be:

$$7{,}250 \text{ KW} \times 24 \text{ hours} = 174{,}000 \text{ KWh}$$

B. NONRESERVOIR SOURCES OF ELECTRICAL POWER AVAILABLE TO NEW PATTONSBURG

Another source of electrical power which could be trapped for the town of New Pattonsburg is the power available from nearby transmission lines.

These lines consist of one 161 KV line and two 69 KV lines. At the present time, however, the KVA capacity available in these lines for additional transmission loading is unknown; but according to Mr. W. L. Altheid, the capacity of these lines is adequate for additional loading.

IV. DISTRIBUTION FOR THE NEW PATTONSBURG TOWNSITE

A. GENERAL PLANNING LAYOUT

An electrical distribution system, or distribution plant, is comprised of the electric power system between the bulk power source or sources, and the consumers' service switches. Distribution systems can be divided into the following categories: subtransmission circuits, substations, primary feeders, transformers, secondary circuits, or secondaries, and consumers' service connections and meters or consumers' services.

In each electric power system, the distribution plant serves the important function of delivering electric power from the bulk power source(s) to the individual consumers. The effectiveness of distribution systems is measured in terms of voltage regulation, service continuity, flexibility, efficiency, and cost. The list factor cost is very important; approximately 50 percent of the capital investment in an electric power system in the United States is in the distribution plant.

The problem of distribution is to design, construct, operate, and maintain a distribution system that will supply adequate electric power to respective load areas, both now and in the future, at the lowest possible cost. Because of differences in load densities, existing distribution plants, topography, and other local conditions, no one type of distribution system can be applied economically to all load areas.

The distribution system designed and built for any given area should incorporate certain basic features. It should be constructed so as to provide service with a minimum of voltage variation, and a minimum of interruption. It should be flexible to allow it to be expanded in small increments, and to meet changing load conditions with a minimum amount of modification and expense. Such flexibility facilitates keeping the system capacity close to actual load requirements, and thus permits the most effective use of system investment. It also largely eliminates the need for predicting the location and magnitude of future loads. Therefore, long-range distribution planning, which is at best based on scientific guesses, can be greatly reduced.

B. THE MAIN TRANSMISSION LINE

In order to determine the size of the main transmission line needed to carry electrical power from other nearby transmission lines to the New Pattonsburg townsite, the total electrical load must be calculated.

Land Use of Projected Area Load Requirements	
Residential	95,400.00 KVA
Industrial	92,000.00 KVA
Commercial	54,750.00 KVA
Public Facility	14,010.00 KVA
Street Lighting	231.00 KVA
TOTAL	≃ 256,400.00 KVA

This total represents the absolute maximum loading of the power distribution system. Such a load would exist if, simultaneously, all lights and appliances were used in the residential areas, and all factories, public facilities, and commercial businesses were in operation at one time. But this is seldom, if ever, the case. Usually, 50 to 60 percent of the total maximum load power is required by a city. Choosing a diversity factor of 60 percent total power loading, the actual power required by the city of New Pattonsburg at any one time would be:

$$256{,}300\ \text{KVA}(.60) \simeq 154{,}000.00\ \text{KVA}$$

or

$$154{,}000\ \text{KVA} \times .85\ \frac{\text{KW}}{\text{KVA}} \simeq 130{,}900\ \text{KW}$$

To accommodate increased electrical power consumption in New Pattonsburg 25 years after the city's population level has reached 50,000, a main transmission ling bringing power into the city should have a capacity perhaps three times that needed for present city loading damands. For this reason, a 161 KV line (AC-SR) aluminum cable steel reinforcement should be used. One end of this line would be connected to the 161 KV line which passes from the south approximately 4.5 miles from the city's limits. The other end of this line would be connected to the 69 KV line which passes from the northwest approximately 5 miles outside the city's limit. This second line connection would require a transformer to step up the line voltage to 161 KV.

This newly installed transmission cable could be brought to the town by an overhead transmission system and then an underground system within the city limits; or it could be buried underground along its entire length. This proposed transmission line would provide the town of New Pattonsburg with electrical powers from two separate sources. In case of power failure at one source, the remaining source could provide the town with all the power needed. Direct interconnection of these lines will preclude any service interruption or power blackout.

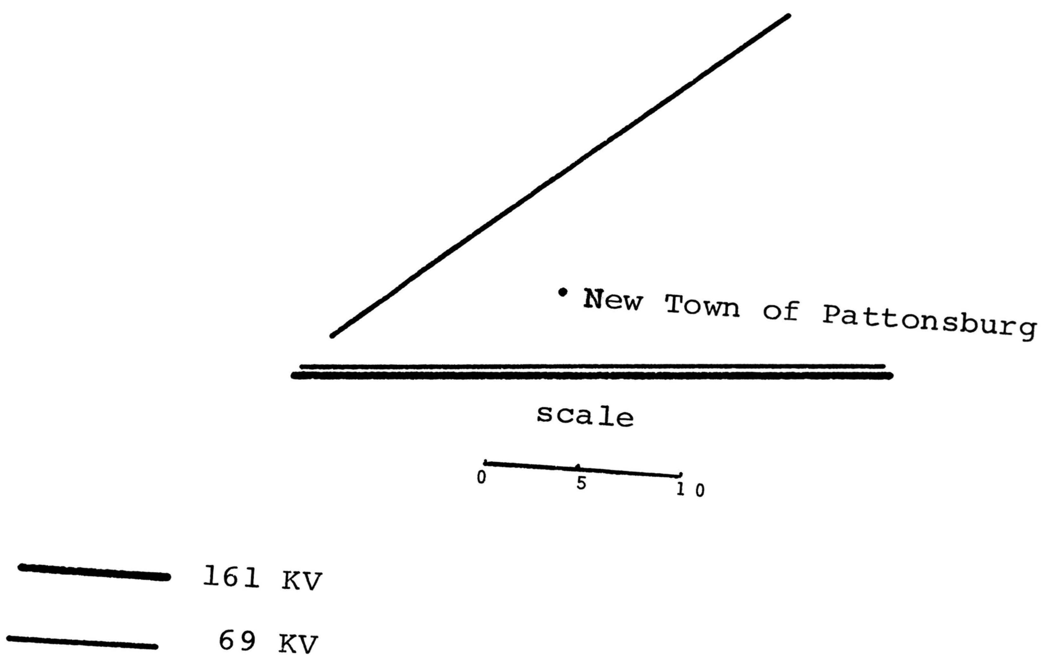
Map 2 shows the route of the main transmission lines which act as the bus or power source for the town of New Pattonsburg.

C. TYPE OF DISTRIBUTION SYSTEM

Most electrical power today is distributed by an a-c system. The following description and discussion of a distribution system is confined to alternating current systems.

Subtransmission power may be transmitted from the bulk power source to the distribution substations through various types of subtransmission circuits. These are simple radial circuits, parallel or loop circuits, or a number of interconnected circuits forming a subtransmission grid or network.

A simple radial system of power distribution is attractive because of its low-cost, initial installation. But the poor reliability of the system adversely affects any such cost advantage and precludes its use.



Map 2. The Location of the New Town of Pattonsburg with Respect to Surrounding Transmission Lines

A loop circuit is that type of circuit which has power lines that originate at a power supply point or bus, pass through and serve a given load area, and return to the same supply point.

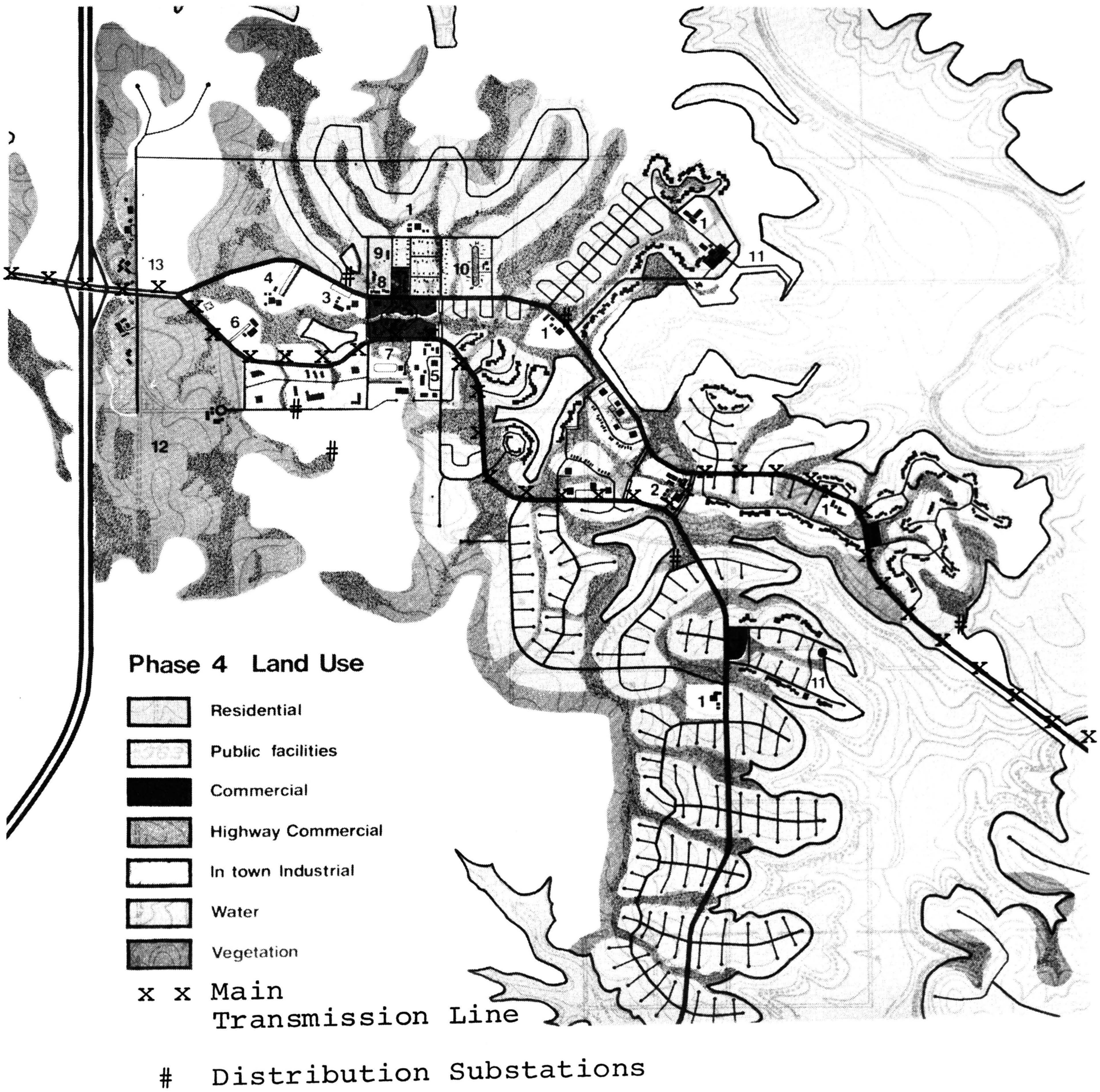
The power capacity of the subtransmission circuit for the industrial park should be 33 KV, using two distribution substations. A step down transformer is needed between the 161 KV main line and the 33 KV lines to the distribution substations. For the non-industrial areas of the city, a 12.740 KV line would be needed with one distribution substation located in the downtown area, and three other substations located in residential areas.

Map 3 shows the 161 KV line and the proposed location of substations.

Figure 6 shows the subtransmission parallel or loop circuit proposed for the New Town of Pattonsburg. On such a circuit, no single fault on any one line would interrupt service to a distribution substation.

D. RECOMMENDED ADDITIONAL PEAK LOAD TRANSMISSION FACILITIES

Earlier, the calculations were made to find the hydroelectric production capacity of the new proposed dam. Calculations based on 91 feet of head and average 1,107.4 cfs indicated a power output of 8,529 KVA, which is a small quantity in comparison to the total average power requirements of New Pattonsburg. This power could be well used to help satisfy peak load requirements of the town. It could also be used to allow pumping of water from the proposed lower



Map 3. The Route of Main Transmission Line and Location of Distribution Substations in Phase 4 Land Use of the New Town of Pattonsburg

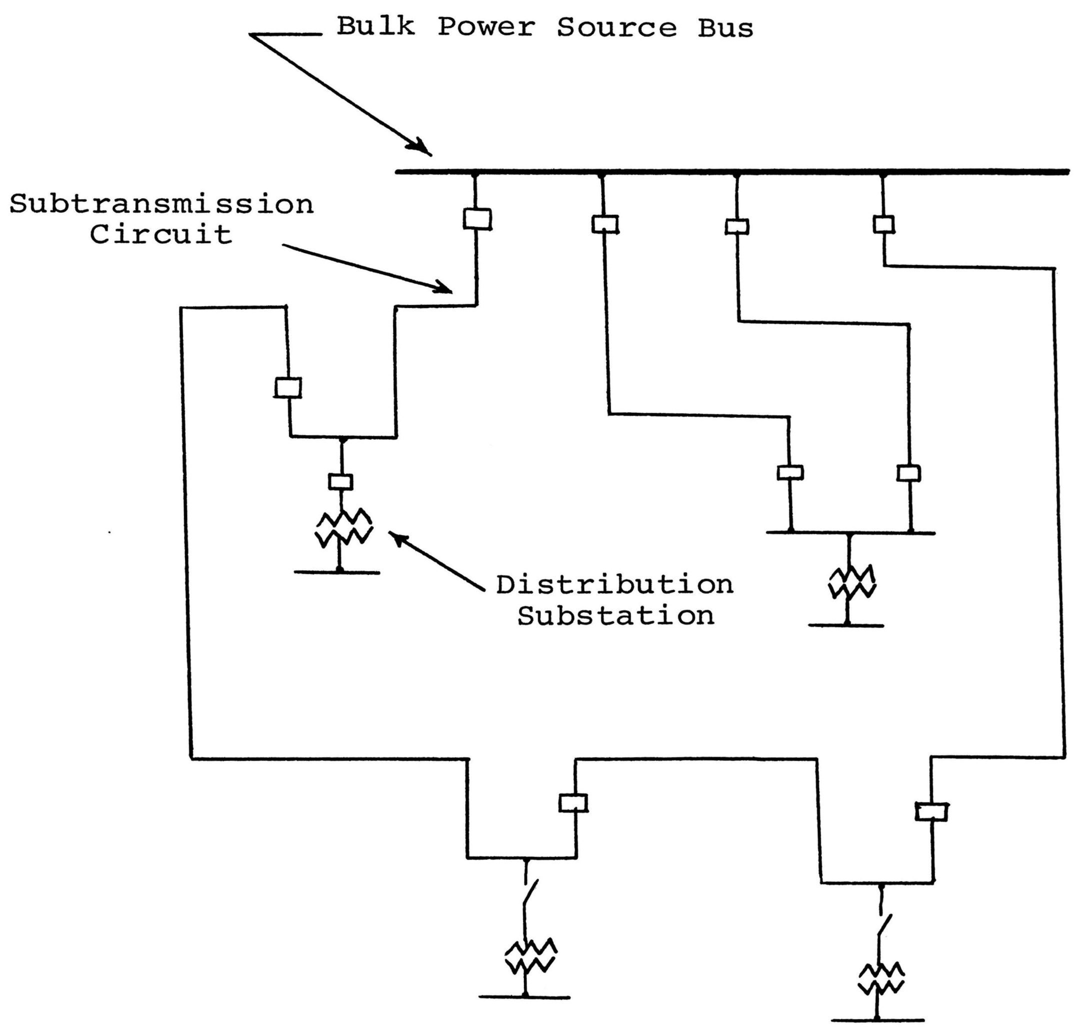


Figure 6. A Parallel- or Loop-Circuit Subtransmission Layout

reservoir to the upper reservoir to maintain safe recreational water level during dry seasons. The electrical power produced at the dam would be transmitted by a 33 KV transmission line to New Pattonsburg and interconnected there with 161 KV line by a step-up transformer.

In view of the relatively short 5-mile distance between the dam and New Pattonsburg, the 33 KV transmission line could practically be run underground everywhere.

E. THE COST OF DISTRIBUTION LAYOUT

Use of underground residential distribution (URD) systems has increased because of the environmental advantage of no visual obstructions. It also has an established record of fewer breakdowns in service and better service safety in use.

The comparison of installation costs with those of overhead systems is now at a favorable ratio of 1:1 (1970) as compared to 5:1 in 1963 as shown in Table XI.

URD is now the rule rather than the exception in urban planning. The only notable disadvantage encountered in URD is the difficulty of pinpointing any breakdown and the increased time needed for repair as compared to overhead system repair.

The record produced by the Conference on Underground Distribution (sponsored by the Institute of Electrical and Electronic Engineers, Chicago, September 27-29, 1966), has been the guiding reference for compiling this cost-estimate on the planned URD for New Pattonsburg.

TABLE XI

Comparison of Underground to
Overhead Power Transmission [18]

Estimated Average Cost Ratio - Underground to Overhead

	End of 1963	End of 1965	Estimated 1970
High	5:1	3:1	2.5:1
Low	1.1:1	1.1:1	0.85:1
Average	2.4:1	1.7:1	1.4:1

Estimated Average Cost Per Front Foot ($)

	End of 1963	End of 1965	Estimated 1970
High	9.10	6.90	6.70
Low	1.68	1.43	1.25
Average	4.95	3.42	2.89

The calculation of the main transmission lines distribution (all underground) cost as follows:

FIRST 154,000 KVA x 11.5 miles x 5.28 thousands of feet/mile x \$0.47/KVA ≃ \$4,400,000.00

SECOND 55,200 KVA x 4 miles x 5.28 thousands of feet/mile x \$0.45/KVA ≃ \$525,000.00

Total Cost of Main Transmission Lines ≃ \$4,400,000 + \$525,000 ≃ \$4,925,000

For secondary residential distribution, \$255 per service point (i.e. residential units-houses) has been the cost figures in similar situations.

14,865 points x \$255/point ≃ \$3,800,000

Total Cost of the Whole Distribution System:

= \$4,925,000 + \$3,800,000 = \$8,725,000

The cost of the whole distribution system as it was planned previously is calculated on the assumed basis of power transmission via 161 KV lines to New Pattonsburg from surrounding transmission lines.

It should be noted that if the same network of trench for underground power distribution is shared with telephone and gas companies for their own distribution system, cost of installation will reduce proportionally.

At the present time, there is no existing source of information to gauge the costs of installing underground distribution networks in Missouri. Consequently, it is difficult to estimate the actual cost for a URD system in New Pattonsburg; but allowing for inflationary price increases, the cost should be approximately 8 to 12 million dollars.

V. CONCLUSIONS

Reviewing some of the assumptions made to provide a working premise for the planning of New Pattonsburg's electrical power system, it seems that the predicted electrical loads for residential areas should be reasonable because of the defined geographical location and corresponding demographic statistics for such an area.

Electrical energy consumption in home and commercial heating was not discussed because technological trends indicate that in the near future, nuclear reactor power generating plants and nuclear reactor steam power plants will replace a percentage of existing fossile fuel burning plants. A by-product of power generation by nuclear plants is thermal energy, such as heat. This generated heat product is today wasted to the environment causing a pollution problem. With future technology, this heat by-product can be distributed to homes and industry for useful consumption.

The assumptions made to plan for the estimated industrial electrical loads are, at best, tentative. The projected number of industrial plants locating in New Pattonsburg may be high.

One major problem is the uncertainity of just what type of industrial products will be marketed within the next 20 years, allowing for social-technological change and advance. Calculations made for industrial power requirements are at least accurate for 1973 type industries, but should be adjusted for any new types of industries originating later.

The planned estimate of electrical loading for commercial and municipal areas and street lighting seems reasonable and accurate, provided state and federal government regulations and requirements do not change.

The estimate of hydroelectric power produced by the new dam was made assuming a head of 91 feet. However, it is not unusual for the water released through a dam to be channeled downstream through a pipeline to increase the head and, in turn, increase the production of electrical energy. For this reason, a 33 KV capacity transmission line was proposed to transmit the hydroelectric power from the dam to New Pattonsburg. A smaller capacity transmission line could handle this 8,529 KVA produced by turbines located at the dam, but could not safely accommodate increased quantities of power produced by turbines located downstream.

It is difficult to estimate with any accuracy the amount of existing electrical energy available to New Pattonsburg on transmission lines surrounding the town. In case of insufficient available energy on these lines, a study should be conducted examining the feasibility of installing an electrical power plant near the town of New Pattonsburg. The 161 KV line could be used to transmit surplus electrical energy for sale to customers outside of New Pattonsburg.

General allowance should be made for adjusting calculated power loads subsequent to introduction of new appliances and equipment designed to improve the comfort and quality of life.

In the distribution layout for the New Town of Pattonsburg, precautions should be taken in order to design, construct, operate, and maintain a distribution system that will supply adequate electric power to respective load areas, both now and in the future, so should be flexible to allow it to be expanded in small increments and to meet changing load conditions with a minimum amount of modification and expense.

With recent inflation and higher costs of construction, it would be wise to design the main transmission line and subtransmission lines circuits to a larger amount of capacity in order to meet the ultimate demand.

The total cost of the distribution layout system for the New Town of Pattonsburg should be approximately 8 to 12 million dollars.

BIBLIOGRAPHY

1. Ogburn, J. A., Royce, D. C., Sieck, L. K., Macy, B. W., et al. Missouri Department of Community Affairs, Pattonsburg: A Regional Approach, September, 1971.

2. Sieck, L. K., et al. Daviess County Development and Pattonsburg, the First Rural New Town, University of Missouri - Rolla, September, 1971.

3. Ogburn, J. A., et al. Comprehensive Development Planning for the Green Hills Region, February, 1972.

4. O'Haver, W. E., Personal Communication, Manager of Rolla Municipal Utility, December, 1973.

5. Nusbaum, W., Personal Communication, Black & Veatch, Box 8405, Kansas City, Missouri 64114.

6. Handbook of Chemistry and Physics, 50th Edition, 1969-70, The Chemical Rubber Company.

7. United States Department of the Interior Geological Survey, Water Resources Data for Missouri, 1971 and 1972.

8. Geological Survey Water Supply, Surface Water Supply of United States, 1961-65, Part 6, Missouri River Basin, Washington, D.C., 1969.

9. Geological Survey Water Supply, Surface Water Supply of United States, 1966-70, Part 6, Missouri River Basin, Washington, D.C., 1971.

10. Linsley, R. K., Franzini, J. B., Water Resources Engineering, McGraw Hill Series, New York, New York.

11. U.S. Department of Commerce Weather Bureau, Evaporation Maps for the United States, Technical Paper, No. 37.

12. Thompson, J. C., Personal Communication, Union Electric Company, St. Louis, Missouri 63101.

13. Oklahoma Gas and Electric Company, Engineering Guide, Oklahoma City, Oklahoma, May, 1967.

14. Altheide, W. L., Personal Communication, Chillicothe, Missouri 64601.

15. Central Station Engineers of the Westinghouse Electrical Corporation, Electrical Transmission and Distribution, Reference Book, Fourth Edition, East Pittsburgh, Pennsylvania, 1964.

16. Federal Power Commission, Electrical Power Statistics, August, 1972, Washington, D.C.

17. Stevenson, W. D., Jr., Elements of Power System Analysis, McGraw-Hill Book Company, New York, New York, 1962.

18. Conference-Record Supplement, Special Technical Conference on Underground Distribution, sponsored by IEEE Power Group, New York, New York, 1966.

19. U.S. Bureau of Census, Census of Population and Housing, 1970 Census Tracts, Final Report PHC(1)-47, Columbia, Missouri, SMSA.

20. The Map of Major Electric Transmission Lines of Missouri, Division of Commerce and Industrial Development, 1967.

VITA

Javad Yousefian was born on November 14, 1944, in Rafsenjan City, Kerman State in Persia Iran. He received his primary schooling education in Rafsenjan City and his secondary education in Tehran. He received his B.S. degree in Electrical Engineering in December, 1970, from the University of Missouri - Rolla.

Mr. Yousefian has been enrolled in the Graduate School of the University of Missouri - Rolla since January, 1972, studying for his M.S. degree in Environmental and Planning Engineering. He was granted a graduate research assistantship during the spring of 1972 and a graduate assistantship during the fall of 1972.

His major interest is Environmental and Planning Engineering.